Analysis of Micro-Grid Control Strategy for Photovoltaic Power Generation System

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Abstract: In order to give full play to the comprehensive advantages of photovoltaic power generation system and micro-grid, based on the current problems of photovoltaic power generation system, this paper proposes a micro-grid control strategy based on photovoltaic power generation system. This mainly includes master-slave control strategies, peer-to-peer control strategies, and power management system control strategies. At the same time, multiple control strategies can be applied comprehensively according to actual conditions.

1. Introduction

As the population continues to increase and the scale of production continues to expand, more energy is needed to meet the normal operation of people's production and life. It can be said that the 21st century is an era of energy. In China, electricity is the main form of energy use. However, in the production process of electric energy, a large amount of renewable energy such as oil and coal is consumed. These energy sources are slow to regenerate and bring environmental pollution to varying degrees. Therefore, it is necessary to optimize the energy structure system, promote the application of new energy sources, and pursue sustainable economic and social development. In addition, in recent years, the requirements for power quality have been continuously improved and the scale of power consumption has been continuously expanded, and the drawbacks of ultra-large-scale power systems have become increasingly prominent. Based on the shortcomings of energy structure adjustment and traditional power grid, a new type of distributed generation technology (DG) is proposed. It has the advantages of high efficiency, economy and reliability, but there is also an obvious drawback. For large power grids, distributed generation is an uncontrollable power supply [1]. In order to overcome the shortcomings of distributed generation and to make full use of the advantages brought by distributed generation, the micro-grid is proposed. The flexible operation mode of the micro-grid and the high-quality power supply service require excellent control systems as support, and the control technology is one of the key technologies of the micro-grid. Therefore, the research on the micro-grid control strategy of photovoltaic power generation system can not only promote the utilization of solar energy, but also improve the quality of power supply and promote the optimization of energy structure.

2. Problems in Photovoltaic Power Generation Systems

Photovoltaic cells convert light energy into electrical energy through solar radiation, which is greatly affected by external temperature and light intensity. In the case of cloudy and rainy weather, the intensity of the light changes drastically and the power output also decreases, then the power output of the photovoltaic power generation fluctuates frequently. This may seriously affect the power quality of the micro-grid to supply power to the load, and may even cause the entire system to collapse. This will result in the stopping of power to the critical load and cause unnecessary losses. In addition, the operation of the inverter in the light load mode is also caused by the power fluctuation of the photovoltaic system, and also causes a series of problems such as an increase in current harmonic content and a malfunction protection device. Photovoltaic power generation is an inverter power supply, and power electronic equipment is a necessary equipment in the power control and power conversion process of the inverter power supply. The superposition of various

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characteristics of the above photovoltaic power generation system complicates the analysis of its output performance. The superposition of dynamic characteristics of each component at different times and at different scales makes the photovoltaic power generation system a strong nonlinear system to some extent.

At first, the design of photovoltaic power generation was not considered for grid connection. The grid connection of photovoltaic power generation will cause a series of problems such as short-circuit current and bidirectional power flow. The operation mode of photovoltaic power generation is different from that of large power grids. The construction of photovoltaic power plants and their implementation are generally private to meet the needs of individual life. This makes it difficult to implement some data acquisition methods that are important for grid control. Therefore, the first purpose of photovoltaic power plant construction is not to meet the needs of the power grid, which will bring a lot of trouble to the safety of the power system.

Photovoltaic generation requirements for transmission lines are also different from AC large power grids. In remote high-voltage transmission lines or medium-voltage distribution lines used in large power grids, the resistance is much smaller than the reactance. The ratio of the reactance (X) to its resistance (R) in a high voltage transmission line is large. Therefore, the main factor causing voltage drop and line power loss is reactance. Photovoltaic power generation systems are different. The size of the transmission line is very similar to its reactance, and the main factor affecting voltage drop and line loss on the transmission line is resistance. Photovoltaic power grid connection will seriously affect the stability of local power grid [2].

The most important issue in the power supply process of the power grid to the load is the power quality. Photovoltaic power generation also has the characteristics that other distributed power generation is controlled by the user. Therefore, the start and stop of the system is determined by its own needs, which may fluctuate the voltage of the distribution network. The load flow that is greatly changed on the distribution line and the difficulty in voltage adjustment and voltage over-standard are caused by the frequent start-stop operation of the PV system. In the future, DG may use a large number of power electronic power sources. The regulation and control methods of voltages are quite different from those of conventional methods, and corresponding control strategies and means are needed to cooperate with them. In addition, power electronic type distributed power supplies are prone to harmonics and cause harmonic pollution.

The impact on relay protection is also great. Photovoltaic systems must match and adapt to relay protection devices that are already present in distribution networks, as these relay protection devices are unlikely to make wide-ranging changes for new photovoltaic systems. In the case of grid connection, if the distribution network fails, the PV system must be removed before the relay protection device overlaps. Otherwise, the arc will be reignited and the reclosing will fail. The photovoltaic system injects power into the grid, which will reduce the relay protection zone and disturb the relay protection device.

In addition, there are problems such as short-circuit overcurrent, ferromagnetic resonance, grid efficiency, real-time monitoring, control and regulation of the power distribution system. The root cause of these problems is that there is a big difference between photovoltaic power generation and existing power systems, and corresponding control strategies and means should be implemented to ensure the normal operation of the system [3].

3. Micro-Grid Control Strategy for Photovoltaic Power Generation Systems

The micro-grid is a small power distribution system formed by a combination of a micro source (MS), a load, an energy storage device, and a control device [4]. The micro-grid powered by photovoltaic cells has the advantages of low cost, low voltage and low pollution, and is generally connected to the user side. The micro-grid is a power source for the user and a small controllable unit for the large grid. On the one hand, it can be reliably supplied to the local load, and on the other hand it can be integrated into the large grid. In the micro-grid, new energy sources such as wind power, photovoltaic power generation and fuel cells are often used as micro power sources. The power generation can be used for industrial and domestic loads in the surrounding area, and excess

power can be integrated into the large power grid.

3.1 Operating Mode of Photovoltaic Inverter Power Supply

The micro-grid can operate in both the grid-connected state and the off-grid mode in island mode. When grid-connected, the micro-grid voltage is affected by the voltage of the large grid. At this time, the current source (CSI) is used to control the photovoltaic power. The photovoltaic power supply has no voltage control link, and the micro-grid central controller controls its output active and reactive power, which is called PQ inverter power supply. When the micro-grid is disconnected from the large grid, the power demand of the load in the micro-grid area is borne by the photovoltaic power source. The PQ control is suitable for the power of the photovoltaic power supply to automatically output the load demand when the grid-connected mode cannot meet the requirements of the independent operation of the micro-grid, adjust the AC bus voltage of the micro-grid and keep the voltage of the micro-grid stable.

Power control methods based on droop characteristics are widely used in photovoltaic power control. The relationship between the power output active power and the voltage frequency droop characteristic is shown in Figure 1(a). The relationship between the output power and the active power of the photovoltaic power source 1 and the photovoltaic power source 2 is represented by curves 1 and 2, respectively. According to the curve, the different output powers of the photovoltaic power supply are different according to the voltage frequency, and the output frequency of the power supply changes with the change of the output power. It can be seen from the figure that when the output frequencies of the two power supplies are the same as fi, the output powers of the power supply 1 and the power supply 2 are P1 and P2, respectively. Only when the output power supply amplitude, phase and frequency are exactly the same, the circulating current will not appear when the photovoltaic power supply is operated in parallel. The schematic diagram of the VSI power supply control based on the droop characteristics is shown in Figure 1(b). After sampling by the inverter power source, the voltage and current signals are output, the current output power is calculated and decoupled, and the amplitude and frequency of the inverter reference signal are obtained by using the droop characteristic equation, and the output power is obtained after the inverter.

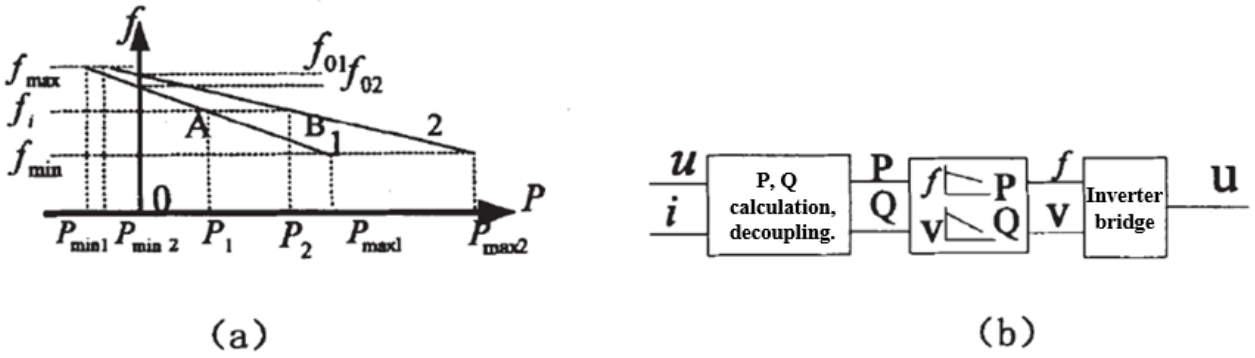

Fig.1 Vsi Droop Control Chart

3.2 Micro-Grid Control Strategy

At present, the micro-grid mainly has a variety of control methods such as master-slave control, peer-to-peer control, power management system control and multi-agent technology.

3.2.1 Master-Slave Control Strategy

The micro-grid mainly adopts the master-slave control strategy when operating on an island. When connected to the grid, the overall capacity of the micro-grid is relatively small compared to the grid. The grid can stabilize the frequency of the system. The micro-grid does not need to adjust the frequency, and only needs to output the specified active power and reactive power. When operating in island mode, the master control unit in the master-slave control system uses V/f control to maintain the system voltage and frequency constant. The general process of master-slave control

strategy is as follows:

(1) When the detection unit detects that the micro-grid and the distribution network are disconnected into the island operation mode, the micro-grid control switches to the master-slave mode, and the main control source of the V/f control adjusts the voltage amplitude and frequency at a stable value.

(2) When the load in the micro-grid changes, the main control source automatically adjusts the output current according to the change of the load to increase or decrease the output power. At the same time, the amount of change of its own power is detected and calculated, and the output specified values of other slave systems are adjusted according to the available capacity of the existing power generating unit, so that the magnitude of their output power changes. As the output power of other slave systems increases, the output of the master source decreases accordingly, ensuring that the master source always has enough capacity to regulate the instantaneous power change.

(3) When there is no other active or reactive capacity that can be called in the micro-grid, it can only be adjusted by the main control source itself. When the load is increased, depending on the voltage-dependent characteristics of the load, it is conceivable to appropriately reduce the voltage value. If the power balance is still not possible, consider implementing the micro-grid by taking measures to remove the secondary load.

3.2.2 Peer-to-Peer Control Strategy

Peer-to-peer control cannot effectively solve the problem of no adjustment of system frequency and voltage. When the micro-grid is seriously interfered by external factors, the system frequency will also fluctuate, which cannot effectively guarantee the stable frequency quality of the system. At the same time, the peer-to-peer control method does not discuss the special operation mode in the transitional switching process.

3.2.3 Control Strategy Based on Power Management System

The control based on the power management system can achieve effective control of the frequency quality of the micro-grid. The control strategy uses different control modules to control active and reactive power regulation while adjusting the balance, and adds a frequency recovery algorithm. The use of different control methods enables the power management system to meet the various requirements of the micro-grid for reactive power, and strengthens the control of performance. This makes the control more flexible. Similarly, the control strategy does not consider switching the operation mode of the micro-grid.

3.2.4 Multi-Agent Based Control Strategy

This strategy enables control of the micro-grid through multi-agent technology. This approach provides a system that does not require frequent administrators. A variety of control performances are gathered in this system to enable decentralized control of the micro-grid. Widely used in market trading and managing energy. However, multi-agent technology is not deep enough in the study of frequency and voltage control. There is still a lot of research work to be done to make multi-agent technology play a bigger role in the micro-grid control system.

4. Conclusion

Based on the advantages of low cost, flexible operation mode and high service quality, the micro-grid based on photovoltaic power generation system is bound to become one of the important power supply methods. However, due to its application in the exploration stage, there are still many immaturities. It needs to adopt relevant control strategies to ensure the stable and safe operation of the micro-grid, so as to give full play to the comprehensive value of the photovoltaic power generation system and the micro-grid. Due to various control methods, multiple control strategies can be used in combination according to actual conditions.

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